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# Off-Axis Beaming 3D-Printed Bull's-Eye Antenna

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**Abstract-** We present a theoretical analysis, along with numerical and experimental results of an off-axis beaming Bull's-Eye (BE) antenna working at 96 GHz. The antenna presents a 17 dB gain beam pointing at  $16.5^\circ$ , with  $-10$ dB side lobe level and  $3.5^\circ$  beamwidth. The prototype is fabricated by 3D printing stereolithography and then copper-coated, resulting in a 75% weight reduction compared to a fully metal fabricated design. Interesting applications in the fields of microsatellites, unmanned aerial vehicles or point-to-point communications are envisioned.

Leaky wave antennas (LWAs)[1] are low profile devices which present radiation characteristics even higher than those achieved by larger volume antennas, such as horn antennas. Among them, a special type of structure is that consisting of a flat metallic slab patterned with periodic grooves surrounding a central radiating slot. Several works have been published [2]–[5], showing different geometries and analyzing their leaky wave radiation mechanism both at microwaves and optics for solid metallic structures. For some applications, lightening the structure and engineering it for off-axis beaming [6] may be of interest.

In this work we present a Bull's-Eye antenna with off-axis radiation. A scheme of the antenna is shown in Fig. 1(a). The deduction of the equation which governs the elliptical grooves' distribution and shape was done by means of a thorough holography analysis and reported in [7]. The central slot width sets the transversal resonance (which fixes the operating frequency at which fed power is coupled to the output side) and its height governs the quality factor. Taking the theoretical values as a starting point, the structure was then optimized by launching numerical simulations with the commercial simulator CST Microwave Studio<sup>TM</sup>. The final design was fabricated by stereolithography and metallized in a four step chemical process followed by an electroplating process, see Fig. 1 (b).

Ideal simulation and measurement [Fig. 1(c, d)] results show good agreement, except for a 4 GHz shift towards higher frequencies in the experimental measurements in both  $S_{11}$  and maximum gain frequency, which takes place at  $f = 92$  GHz for the simulation. A decrease of about 3 dB appears in the experimental gain (peak gain of 17 dB), which is probably due to fabrication tolerances and possible extra losses introduced by the metal roughness, whereas a slight deviation of approximately  $1.5^\circ$  in the beaming angle ( $\theta = 16.5^\circ$ ) might be due to additional experimental errors.

To unveil the origin of the disagreement, the final prototype was inspected under a microscope and the measured dimensions were included in the simulation model. Figure 1 (c) and (d) display the  $S_{11}$  and E-plane radiation diagrams at the simulated design frequency  $f = 92$  GHz, (black curves) and experimental frequency  $f = 96$  GHz (red curves), respectively. It can be seen in Fig. 1(c, d) that the final simulation model (blue curves) provides a better agreement with the experimental results with only a reduction of 1dB in the peak gain.

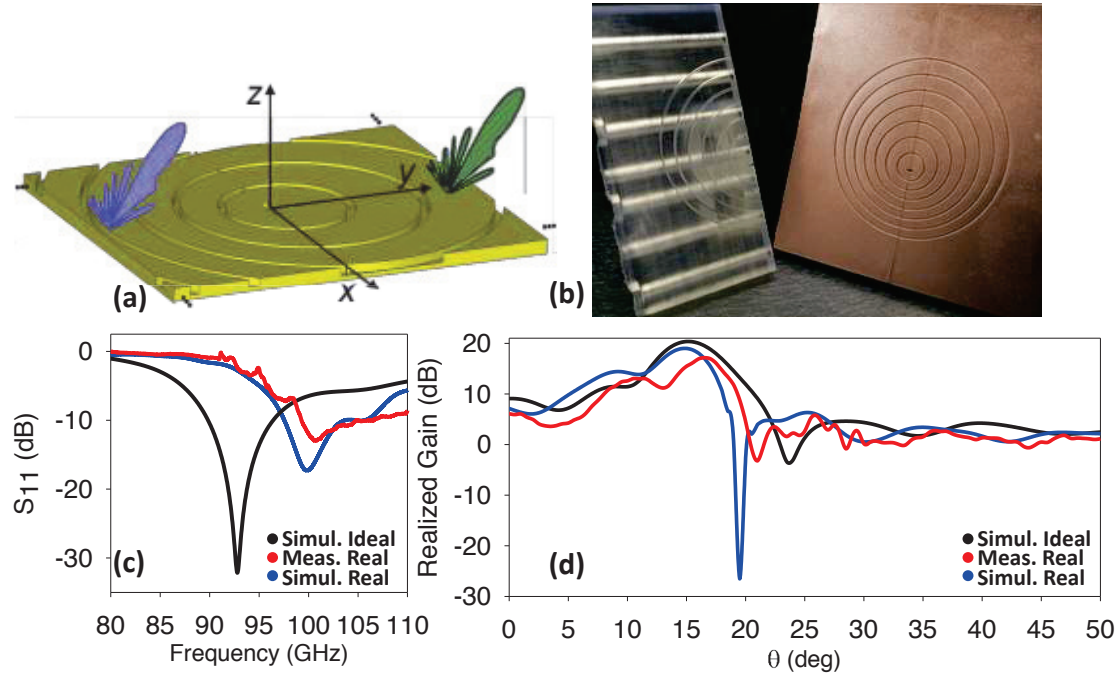


Figure 1. (a) Schematic of an off-axis Bull's-Eye. (b) Picture of printed non-coated half antenna and coated antenna. (c, d)  $S_{11}$  and E-plane radiation diagram for simulated ideal (black curve), measured real (red) and simulated real (blue curve) antennas, respectively.

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